1891

PURDUE UNIVERSITY

AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 35, VOL. II, MARCH, 1891.

(1) Loose smut of oats.

Issued March 30, 1891.

Published by the Station:
LAFAYETTE, IND.
U. S. A.

Occurrence of Oat Smut.

The loose smut* of oats was apparently in the same abundance last year (1890) as heretofore. As an indication of what might possibly be found in any oat field in the state by careful inspection, we cite the experience of the Station during the last season. The Experiment Station is cautious about the seed used on its farm, yet by actual count in different parts of the several fields the oat crop showed 18.4 per cent. of smut. But, on account of the contracted head and short straw of the affected plants, these fields did not appear noticeably smutty, and would not have suggested to a casual observer anything unusual or especially indicative of loss.

The Station farm raised the past season about fifteen acres of oats, giving an average yield of thirty bushels to the acre (unusually light because of the unfavorable season), making a total harvest of 450 bushels. If no smut had appeared in the crop the yield would have been 550 bushels. Thus the presence of a little over 18 per cent. of smut lost the Station 100 bushels of oats for the season, or about $35.00 in market value.

The reader who supposes this loss is hypothetical or that to have averted it would have cost enough more in seed, labor, soil exhaustion, or something else, to have entirely or quite offset the larger yield, is much mistaken. It has cost just as much from beginning to end to raise the stalks of smut, which give no return as if they were loaded with good grain. The seed germinated and grew into the plant; the plant absorbed the fertility of the soil; it blossomed, and would have been crowned with grain, but for the fact that the farmer sowed smut with the seed. So a certain per cent. of the labor and cost of the seed, the planting, harrowing and drilling during seed time, and the reaping and threshing during harvest time, have been thrown to the winds in black dust.

It seems hardly necessary to point out the absurdity of the opinion held by some farmers, that the presence of smut in a crop actually increases the yield, or at least indicates a better yield than when absent. It has probably arisen from the fact that smut is more conspicuous in a heavy stand of grain than in a light growth, and hence oftener attracts attention in seasons of good harvests. If one considers the way in which smut enters and grows within the plant (described in a former

*In a former bulletin (No. 28) I called this form "black" smut, but the term "loose" seems much preferable, far more distinctive and not so likely to lead to confusion. In adopting it I have followed Kellerman and Swingle in their excellent and comprehensive treatment of the subject in the Second Annual Report of the Kansas Experiment Station for 1889, page 213–287.

bulletin, No. 28), it is evident that the presence of smut in any one plant can not affect the growth of the plant standing beside it. Each individual oat plant flourishes or languishes quite independently, so far as the presence of smut is concerned.

The first close estimate of the proportion of the oat crop destroyed by smut was made in New York* in 1884. It was found upon careful count that a field not noticeably smutty gave nearly 10 per cent. loss, the variety being White Australian. Again† in 1886 a crop of White Russian oats on the same farm was found to have 8½ per cent. smut. In Kansas‡ the fields about Manhattan proved to contain 14½ per cent. of smut in 1888, and in the following year 8 per cent. These estimates were all in fields under ordinary cultivation, and not sufficiently smutty to attract attention.

The loss from oat smut is quite general. Taking into consideration the above facts together with evidence from other sources, it is safe to say that not less than an average of 10 per cent. of the oat crop of Indiana is yearly lost by the presence of loose smut.

In 1889 the crop amounted to 28,710,935 bushels for the State. According to our estimate of loss, this was but nine-tenths of the yield that would have been secured with an absence of smut, and consequently the farmers of Indiana would have been richer that year by 3,190,104 bushels of oats, or at the low market price of 25 cents a bushel, by $797,526, if they had taken the precaution to keep their fields free from smut. Is not this a sum worth looking after?

In 1890, the crop was not so heavy, being 15,566,207 bushels for the state, or an average of about 15¼ bushels per acre. Without smut the crop would have given a return of 17 bushels per acre, estimated as above, and a total yield of 17,295,785 bushels. That is, oat smut took 1,729,578 bushels from the farmers' bins last year, representing at 35 cents a bushel a value of $605,352. Again, is not this a sum worth looking after?

The efforts of practical botany have been directed, especially for the last few years, toward some measure for preventing loss from smut, and have very recently hit upon means of doing so that are simple, inexpensive and thoroughly successful. The earlier efforts were chiefly in the line of ascertaining the cause and action of the smut. It was definitely proven long ago that smut in the crop came largely from sowing smut with the grain. That if the black smut dust adhered to the kernels when sown the crop would be smutted.

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*Arthur, Third Ann. Rep. N. Y. Exper. Station for 1884, page 382.
†Plumb, Fifth Ann. Rep. N. Y. Exper. Station for 1886, page 126.
‡Kellerman and Swingle, Second Ann. Rep. Kans. Exper. Station for 1889, page 223.

There are two ways of securing clean seed, and thereby raising a crop free from smut: one is to obtain seed from a source known to be smut free, and the other is to kill the smut attached to the kernels before sowing. Owing to the general prevalence of smut the former method is unreliable, and the latter is the one to depend upon.

Hot Water Treatment to Destroy Smut.

The latest development of the subject has shown that by applying scalding water to the seed the adhering smut can be readily killed without injuring the grain. In fact there appears to be a range of ten to twenty degrees between the temperature which will injure the oats and that which will kill the smut spores adhering to them. This discovery* has led to a method of treatment that promises to be one of the most effective and simplest preventives known for plant diseases. Everything needed for the treatment can be found in any farm house, and only requires a small amount of time and trouble in the application. *Dip the seed oats into hot water of the right temperature for a certain length of time, then dry, and they will be free from smut, and as good for sowing as before.*

The two items of temperature and time are very important, for if the water is not hot enough the spores are not killed, and if too hot not only the spores but the seeds are killed. The same dilemma presents itself regarding the length of time the grain is immersed in the hot water: too short a time is ineffective, too long a time is injurious.

It has been ascertained by Jensen† that the treatment of oats with water at 127° to 133° F. for five minutes kills the smut without apparent injury to the seed. The lower limit, however, was not invariably successful, and the temperature at which the seed would be injured was not ascertained. Kellerman and Swingle‡ found that oats treated with hot water at 132° F. for fifteen minutes gave a crop without a trace of smut. No other tests of the hot water treatment of oats, besides those of Jensen in 1887 and 1888 and of Kellerman and Swingle in 1889, just cited, have yet been published.

In order to secure further data on the subject the following experiment was carried out during the season of 1890. Twelve lots of oats (New Brunswick) of about 9 ounces each (250 grams) were placed sepa-

*Made by J. L. Jensen, Director of the Bureau of Cereals, Copenhagen, Denmark, in 1887.

†Gardeners' Chronicle, 3rd. ser., iii, 1888, page 555; Jour. Roy. Agric. Soc., xxiv, 1888, pp. 408, 410.

‡Bull. Kans. Exper. Sta., No. 8, 1889, page 96; 2nd. Ann. Report Kans. Exper. Sta. for 1889, page 247.

rately in bags of loose muslin (cheese cloth) and each plunged into scalding water of temperatures varying from 120° to 150° F. and for different lengths of time, in accordance with the following schedule:

120° F. for	———	———	——— 20 min.
125° F. "	———	10 min.	15 min.
130° F. "	5 min.	10 min.	15 min.
135° F. "	5 min.	10 min.	
140° F. "	5 min.	10 min.	
145° F. "	5 min.		
150° F. "	3 min.		

The oats were kept stirrred while in the water in order to heat them uniformly. When removed they were held for a few minutes under a tap of cold water and brought nearly or quite to the room temperature. They were then emptied from the bags and spread upon papers laid upon the floor in a room at ordinary temperature. The next day they were apparently quite dry. On the second day each lot was again weighed and found to have lost from two- to three-tenths of an ounce (6 to 8 grams), that is from two-and-a-half to three-and-a-half per cent. A subsequent trial, in which the hulls were separated from the kernels, appeared to show that the larger part of the loss did not come from the kernels but from the lifeless hulls.

Duplicate sets of about an ounce (25 grams) were taken from each lot and sown by hand in the open ground in drills sixty-six feet long. The duplicate drills were eight inches apart, and with twelve inches between the several lots: thus the drills alternated eight and twelve inches apart. The first and every third set of duplicate drills were sown with the untreated oats for purposes of comparison. All the drills came up well, and gave a good stand of grain.

The amount of the smut in this experiment was determined July 18th, just before harvest. All the drills of treated oats taken together, twenty-four in all, gave but two smutted panicles, which were from the seed treated at 125° F., while the untreated drills, fourteen altogether, gave 99 smutted panicles, being from two to twelve in each drill.

The low percentage of smut (averaging about 1.1 per cent.) in the untreated portion was unexpected, as the seed from the same bin sown in the field gave over 18 per cent. of smut as already stated. The difference might have been due to the extra screening and handling which was given the seed in order to make it more uniform.

It is, however, sufficiently apparent that the hot water treatment accomplished what was desired of it: in every instance reducing the amount of the smut, and at the higher temperatures entirely preventing it.

RELATION OF TIME AND TEMPERATURE FOR SUCCESSFUL TREATMENT.

As already said, the two items of temperature and time are very important, for if the water is not hot enough the spores are not killed, and if too hot not only the spores but also the seeds are killed; and likewise too short a time is ineffective, and too long a time is injurious.

When the schedule of treatment already given was arranged it was supposed that the limits of vitality of the oats had been exceeded. But this proved far from true. The field tests gave no indication of injury from even the severest treatment. The more exact laboratory tests, however, showed five to seven per cent. lower germination for each of the three highest lots, viz: 140° for ten minutes, 145° for five minutes and 150° for three minutes. This conclusion is based upon the results derived from testing 1,000 seeds of each lot, or a total of 13,000 seeds. The accompanying diagram will help to give a clear conception of the relation of time and temperature to the limit of safe treatment.

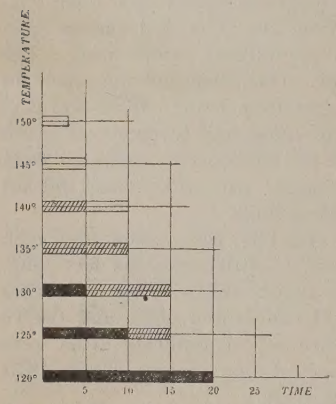


FIG. 1. Diagram showing the result of the hot water treatment of oats: the black spaces indicate that smut was not entirely removed; shaded spaces indicate entire removal of smut with no injury to grain; light spaces indicate a slight injury to the grain. The time is given in minutes, and temperature in degrees Fahrenheit.

The results of the field work were not sufficiently satisfactory, owing chiefly to the unfavorable season, to clearly bring out the lower limits of time and temperature required for removing all smut from the crop. The limits given in the diagram are thought to be approximately correct.

It is apparent, however, that there is an ample range to meet all practical requirements between the lower limit at which the smut is thoroughly destroyed and the upper limit at which injury to the seed begins to show. It follows that the point to be selected for practical treatment should lie midway between these two limits. This point is not far from 135° F. for 5 minutes. But 140° F. for the same time would do no injury, and even five degrees higher yet would do slight harm.

Now it is difficult in practice to maintain a uniform temperature for even so short a time as five minutes. The method to be pursued, therefore, is to place the seed in water at 140° to 145°, and allow the temperature to drop as it will, so long as it does not fall below 130°. If,

however, it should by accident drop below 130°, the time must be extended over five minutes. After each quantity of seed is treated the water is brought up to the required temperature again, ready for the next application.

The method makes it much easier to treat the seed, than when required to hold the bath up to a certain fixed temperature, as heretofore advocated; and it also does away with the necessity for a second vessel of moderately warm water in which the seed is placed for a short time to warm it prior to immersion in the hot water.

Effect of Hot Water Treatment upon the Growth and Yield.

Whether the hot water treatment has any effect on the growth and yield of the crop, either deleterious or beneficial, is an interesting question. The experiment just described, which owing to the unfavorable season was not as pronounced in the results as it should have been, gave some evidence that the treated seed made a better growth than the untreated.

The oats were sown May 6th., and came up well, but proved to be a little too thick. On May 13th., they were half an inch high. Careful notes of the appearance of each lot were taken from day to day to ascertain which treatment, if any, affected the growth. The apparent differences were slight, but so far as they went were in favor of the treated seed, and particularly so for that treated for ten minutes at 130° F., and for five minutes at 135° F.

When the plants were full grown a careful estimate was made of the average height of the stalks for each lot based upon about a score of actual measurements along each drill. The average for all the untreated drills was 34 inches, and for all the treated drills 35 inches, showing an increased growth in height of one inch, in favor of the treated portion.

The oats were harvested July 21st, and threshed out Aug. 7th. The yield was very light. The average per double drill was about 21 ounces for the untreated portion and nearly 23 ounces for the treated portion; showing a gain for the side of the hot water treatment of nearly 7 per cent.

The improved yield of oats treated with hot water has also been observed by Jensen,* who obtained an increased yield of nearly 5 per cent., and also by Kellerman and Swingle,† who obtained an increase of nearly 20 per cent. In the Kansas experiments the seed was treated

*Jensen, Ueber die Verhuetung des Kornbrandes, 1890, page 3.

†Kellerman and Swingle, 2nd Ann. Rep. Kansas Exper. Station for the year 1889, p. 247.

with hot water at 132° F. for fifteen minutes. When harvested both the straw and the grain were weighed, with the following results:

YIELD OF OATS IN KANSAS IN 1889,

on two plats of 467 square feet each.

	Untreated, in pounds.	Treated, in pounds.	Per cent. increase.
Straw.....	28¾	44¾	55.6.
Grain.....	18¼	21¾	19.1.

The authors remark that "it is impossible to account for the great superiority of [the treated plat] over the others, unless, besides killing the smut, the Jensen treatment also caused the seed to germinate better."

EFFECT OF HOT WATER TREATMENT UPON THE VITALITY OF THE SEED.

The germination of the treated and untreated oats was carefully tested in the laboratory in a Geneva germinator. The results showed that the untreated seed gave a total germination of 95 per cent. out of 1,000 seeds, and the treated seed 92 per cent. out of 12,000 seeds. But we have already seen that three lots of the seeds used in these tests were somewhat injured by the very hot water. If, therefore, we take only the results of treatment at 140° for five minutes and lower, which embraces all the lots within the limits of practical service, the total germination was 94 per cent. out of 9,000 seeds, which is but a trifle under the untreated seed, and a difference of no practical moment.

The germination tests had not progressed very far when a most interesting difference between the behavior of the treated and untreated lots attracted attention. It was noticed that the treated lots germinated much faster as a rule than the control seeds. The completed data proved this indication to be true for all the treated seed from the lowest up to and including that at 135° for five minutes; above this point, however, there was no increase, but instead more or less decrease in the rate. This is shown in the accompanying table in which each line represents the results from the use of 1,000 seeds, tested at different dates in lots of 100 each. The large number of seeds in so many duplicate sets must necessarily nearly or quite eliminate accidental variations, and give results of constant value.

RATE OF GERMINATION OF OATS.

The thousand seeds of each sort were tested in ten sets of 100 each at different dates. The percentages of germination for 24 hours and for 48 hours are reckoned on the number of total germinations, and not on the number of seeds placed in the germinator at the start, thus giving the true proportion of germinations for these periods.

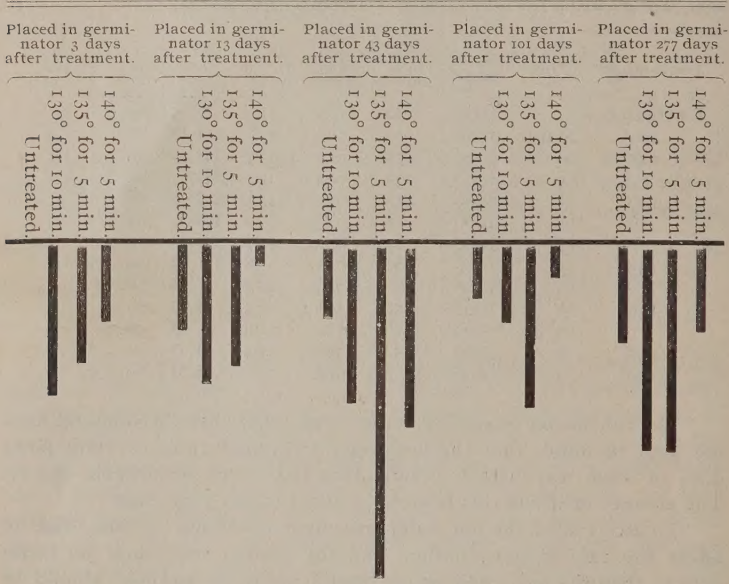
Temperature.	Time.	No. seeds.	Germ. in 24 hours.	Germ. in 48 hours.	In 3 da. and over.	Per cent in 24 hours.	Per cent in 48 hours.	Total per cent.
Untreated	.....	1000	70	735	149	**7.3**	84.3	95
120°	20 min	1000	103	666	173	**10.9**	81.6	94
125°	10 "	1000	175	651	127	**18.3**	86.6	95
"	15 "	1000	235	604	101	**25.**	89.2	94
130°	5 "	1000	218	601	111	**23.4**	88.1	93
"	10 "	1000	128	647	157	**13.4**	83.1	93
"	15 "	1000	125	603	187	**13.6**	79.5	92
135°	5 "	1000	161	671	98	**17.3**	89.4	93
"	10 "	1000	68	644	224	**7.3**	76.1	94
140°	5 "	1000	59	595	283	**6.3**	69.7	94
"	10 "	1000	16	420	428	**1.8**	50.4	86
145°	5 "	1000	58	568	264	**6.5**	70.3	89
150°	3 "	1000	53	564	271	**5.9**	69.4	89

The conclusion seems inevitable, especially when all collateral facts are kept in mind, that the hot water treatment up to a certain point does in some way hasten germination in a very remarkable degree. The manner in which this is brought about is not very clear.

To ascertain if the hot water treatment would not in time cease to affect the rate of germination, and the treated seed show no faster growth than the untreated, as one would naturally suppose should be the case, sets of treated and untreated seeds, 100 in each lot, were placed in the germinator at intervals of ten days, for six consecutive trials, then a duplicate trial after 101 days from treatment, and finally a duplicate trial after 9 months. The results proved quite surprising, and from an economic point of view highly satisfactory. No material difference was apparent in the rate of germination in any of the tests, whatever the length of time that had intervened between the treatment and the germinating test, even up to nine months, the time of the last trial. The seeds were kept in the warm laboratory store-room during the interval, and in all the tests were put into the germinator dry. The following diagram will serve to bring out the fact of the persistence of the added vigor with additional clearness.

GERMINATION AT INTERVALS AFTER TREATMENT.

Number of germinations out of 100 seeds taking place within 24 hours. Each sixteenth inch in length represents one germination. Temperature during germination was variable, which accounts for the unevenness between lots of the same sort.



The practical deductions are that the farmer may treat his seed oats with hot water at his convenience; and whether the seed is sown at once or after a time the benefits to be derived both from killing the smut and enhancing the vigor of the seed will be duly obtained.

Copper Sulphate and Hot Water Methods Compared.

Various chemical substances have for a long time been in use to kill the smut in seed grain, the most efficient being iron sulphate and copper sulphate. The latter, known also as blue vitriol and blue stone, has always been considered the most serviceable, and has had extensive application on the continent of Europe and in California. Up to the time of the discovery of the hot water treatment it was, without doubt, the best preventive for smut known, and was recommended for that purpose in a former bulletin of this Station (No. 28), and is still advocated by others.

The two methods were used on the Station farm last year (1890), and although not tried for the special purpose of testing the methods, the results are interesting, and may be briefly referred to in this connection. The trials were under the supervision of Prof. W. C. Latta, who kindly permits me to use his data.* The oats were sown with the field drill, two and a half acres with seed treated with copper sulphate, one acre treated with hot water, and three-eighths of an acre with untreated seed. A variety of commercial and barn-yard fertilizers was applied to the soil, alternating with portions unfertilized.

The facilities for treating the seed were only such as any farmer has at hand, the work being done by the farm laborers who are of the same class of workmen employed on other farms. Although the process is a very simple one, yet a description of the exact method of handling the seed may be of service to others who contemplate the treatment of their own seed grain. At my request Prof. Latta has written out the following account of the work done on the Station farm:

"In treating oat seed last spring we used cold rain-water with one pound of copper sulphate to one gallon of water. A common wash-tub was filled about two-thirds full with water, and enough finely powdered sulphate put in to give the strength just stated. A bushel of seed was put into a coffee sack (any sack made of coarse open cloth will do) tied near the top of the sack and immersed five minutes in the copper sulphate solution, turning and kneading the sack so as to thoroughly wet all the seed. The sack was then placed on bars across the top of the tub to drain a minute, after which the seed was spread thinly upon an airy floor. The process was repeated with another bushel of seed, and so on until enough had been treated. To hasten the drying and prevent much swelling of the seed, it was dusted heavily and repeatedly with land plaster (sifted air-slacked lime will answer as well), and mixed thoroughly. It is well to continue the stirring every few minutes for a few hours; and if the seed can be exposed meanwhile to the sun, or to a good current of air, so much the better. As each bushel will take up a part of the solution, it must be replenished from time to time, adding both water and copper sulphate in the proper proportions. Be sure that the copper sulphate is finely powdered, or the solution will be too weak at first and too strong at the last. A man and boy can treat six or eight bushels of seed in an hour."

"In treating with hot water we filled two wash-tubs, each about two-thirds full, keeping No. 1 at 125° to 130° F. and No. 2 at 130° to

* Part of the data has already been published incidentally in Bulletin No. 34 of this Station, pages 67-70.

133° F.† The seed inclosed in a sack, as in the copper sulphate treatment, was immersed in tub No. 1, then drained a few seconds and immersed five minutes in tub No. 2. The first tub was used simply to warm the seed and prevent reducing the temperature below 130° in the second tub. The seed was spread and dried as in the treatment with copper sulphate. Care must be taken to add hot water from time to time to maintain the proper temperature."

I am informed by Prof. Latta that the oats treated with hot water came up about two days earlier, and those treated with copper sulphate about as much later than the untreated oats, and that the yields were about 33 bushels to the acre for the hot water treated oats, 28 for the untreated and 24 for the copper sulphate treated.

The percentage of smut and the height of the stalks in these three fields are given in the following table:

SMUT IN TREATED AND UNTREATED OATS.

	No. stalks counted.	No. smutted.	Per cent. smut.	Height of healthy stalks.	Height of smutted stalks.
Untreated	1554	286	18.4	40 in.	33 in.
Copper sulphate (1 lb. to 1 gallon of water.)	1491	1	.067	36 in.	30 in.
Hot water (130° to 133° F. for five min.)	1486	8	.53	38 in.	30 in.

The presence of a half of one per cent. of smut in the hot water treated portion shows that the water was not used quite hot enough to kill all the adhering spores; it should have been about five degrees hotter. The comparative height of the stalks in the three fields does not accord with the results from other experiments, but the reason of the discrepancy is not known.

My attention has been called to another important difference between the three sets of oats by my colleague, Professor Huston. He points out that on the unfertilized plats there was less weight of straw, in proportion to the amount of grain harvested, on those treated with hot water than on the untreated ones, and both were superior in this

† The season's results show that the water in tub No. 2 should have been kept fully five degrees hotter.

respect to the plats treated with copper sulphate. The only fertilized plats which could be used for comparison were two receiving a complete commercial fertilizer, consisting of dissolved bone black, sulphate of ammonia and muriate of potash, at the rate respectively of 140 lb., 290 lb and 85 lb per acre. One of these plats was in the field treated with hot water and the other in the one treated with copper sulphate. No untreated and similarly fertilized plat was available. The ratios in this case are not so divergent, but accord reasonably well with the unfertilized plats. The data are brought together in the accompanying table.

COMPARISON BETWEEN WEIGHT OF GRAIN AND STRAW.

Area in acres.	Treatment of seed.	Application to soil.	Ratio of grain to straw.
3-tenths.	Hot water	Nothing	1 : 1.3
3-eighths.	Nothing	Nothing	1 : 1.8
3-tenths.	Copper sulphate	Nothing	1 : 2.0
1-tenth.	Hot water	Dissolved bone-black, 14 lbs. Sulphate of ammonia, 29 lbs. Muriate of potash, 8½ lbs.	1 : 1.4
1-tenth.	Copper sulphate	Dissolved bone-black, 14 lbs. Sulphate of ammonia, 29 lbs. Muriate of potash, 8½ lbs.	1 : 1.7

The germinating power of the treated seeds was tested by placing 200 seeds of each lot in a Geneva germinator the same day they were treated. The untreated gave a total germination of 98%, those treated with copper sulphate 67%, and those treated with hot water 99%. The germination of the copper sulphate lot proved to be very abnormal. On the second and third days some half dozen seeds pushed their rootlets. For the next two days there were no germinations, and the rootlets previously formed were killed by the copper sulphate taken up by the cloths of the germinator from the outside of the grain. On the fifth day the seeds began to show life again, but instead of pushing out the rootlets in the normal order, they pushed plumules first. It was not till the ninth day that rootlets again began to appear, and then they did not come from the basal end of the seed, but from the sides of the caulicle, in fact they were secondary roots starting for the most part from the first joint of the stem or tillering point. Often so much growth of stem occurred before the roots appeared, that when they did show it was from the sides of the stem full an inch or more above the seed, the primary roots not starting at all.

To learn how the copper sulphate treated oats in the field were coming on, a handful of soil from one of the drills was brought into the laboratory two days after sowing, and the grain (42 seeds) picked out and placed in the germinator. The result of this test is given in the accompanying table, from which it appears that the soil absorbed part of the copper sulphate adhering to the outside of the seed and rendered it less destructive to the young plant.

GERMINATION OF COPPER SULPHATE TREATED OATS AFTER LYING TWO DAYS IN MOIST EARTH.

	1st day	2d day	3d day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day	14th day	Rotted.	Total germ.	Per ct. germ.
Rootlets,	0	4	11	6	5	2	2	3	4	2	0	0	1	1	1	41	98
Plumules,	14	21	2	1	2	0	1	0	0	0	0	0	0	0	1	41	98

But even with the favorable assistance of the moist earth most of the primary roots were killed before starting, and the secondary ones which took their places were consequently late in appearing. This action of the copper sulphate in killing the primary roots and retarding germination has been known for some time, although but few observations have been recorded. Nobbe‡ in his handbook of seeds has figured the seeds of barley and timothy after six days in the germinator, showing at this stage long roots on the untreated and entire absence of roots on the treated seeds, but with the plumules well developed in both cases.

The unusual behavior of the copper sulphate treated seed in largely pushing the plumules before the formationof the roots suggested a further study of the matter. A duplicate set of 100 seeds each from the same lot of oats just described were placed in the germinator at ten-day intervals (with one exception), the last being 78 days from the time of treatment, and the number of roots and plumules appearing each day separately recorded.

It revealed the fact that eleven weeks (78 days) after the treatment practically the same results in the rate and percentage of germination were obtained as with seed freshly treated. The copper sulphate set still

‡ Nobbe, Handbuch der Samenkunde, 1876, p. 276.

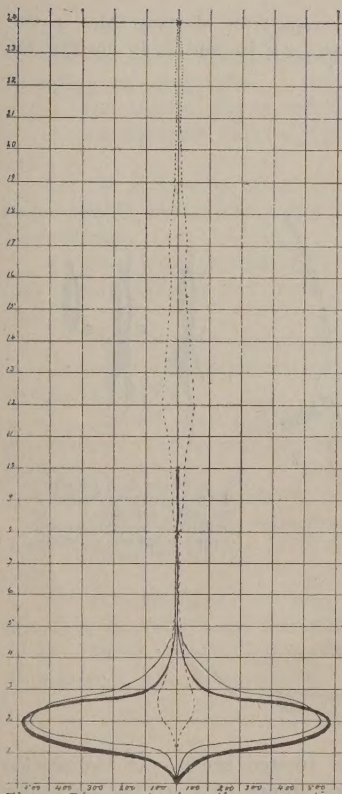


Fig. 2. Diagram to show the comparative rapidity of the germination of oats treated with hot water and copper sulphate contrasted with untreated seed.

pushed fewer roots than plumules, and two-thirds of them appeared in the reverse order. Of those treated with hot water, out of 1600 seeds on which observations were taken, only three produced roots and plumules in the reverse order, and of the same number of untreated seeds seven did so. It seems fair to suppose that in these cases the seed had sustained some mechanical injury, and that the failure to form primary roots was entirely accidental.

In this set of germinations as in the other tests which have already been discussed the hot water treated seed germinated much more rapidly than the untreated, and continued to do so when kept dry seventy-eight days between the time of treatment and germination.

The comparative rapidity of germination is graphically illustrated by the diagram (FIG. 2), in which the light line represents the untreated, the heavy line the hot water treated and the interrupted line the copper sulphate treated seed. This diagram is based on a test with 1600 seeds and brings out clearly the quickened growth of the hot water treated seed and the greatly retarded growth of the copper sulphate treated seed.

The comparative rate of growth can be judged from the illustrations on following page (Figs. 3 and 4), which show representative kernels taken from samples of seed placed in the germinator February 25, 1891, that is 319 days after treatment. On the third day both the untreated and hot water treated seed had started, the latter being somewhat in advance, but the copper sulphate seed remained apparently unchanged (Fig. 3). Pulling apart the hulls, however, revealed the plumule about two-thirds the length of the kernel. The three selected grains, after being drawn, were placed on moist blotting paper in a glass vessel to give them

suitable light and moisture. At one week from starting (Mar. 4) the plumules measured respectively 5¼ in., 4½ in. and ⅞ in. for the hot

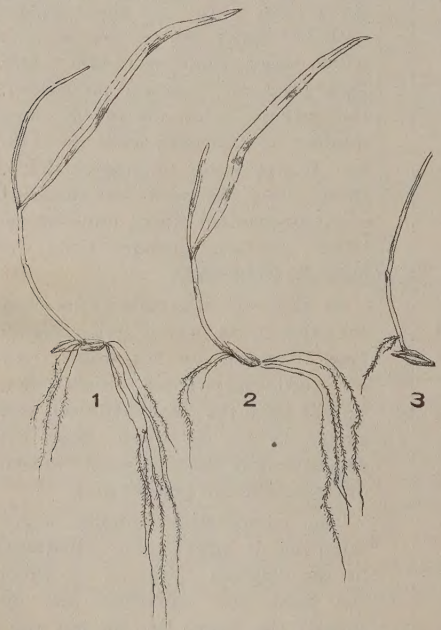


Fig. 4. Two weeks growth on moist blotting paper of oats treated with hot water (1), untreated (2), and treated with copper sulphate (3). ½ natural size. *Original.*

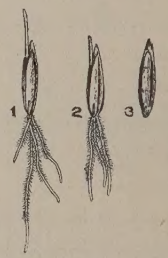


Fig. 3. Three days growth in the germinator of oats treated with hot water (1), untreated (2) and treated with copper sulphate (3). Natural size. *Original.*

water, untreated and copper sulphate treated seeds. At two weeks (Mar. 11) the three grains were again drawn (Fig. 4): the hot water treated seed showed marked increase of growth over the untreated seed, in stem, roots and leaves, while the copper sulphate treated seed had made comparatively small growth, the first complete leaf not having yet expanded and no primary roots having started, and even the cauline roots being much smaller than in the other two seeds.

It appears from the preceding results obtained from the field and laboratory, viewed from several standpoints, that there can be no question of the superiority of the hot water treatment over the copper sulphate one, both being thoroughly efficacious in preventing smut when properly applied, but the latter retards the growth and decreases the yield, while the former accelerates the growth and increases the yield.

SUMMARY.

The foregoing statements and deductions may be summed up in the following paragraphs:

1. The annual loss on account of smut in the oat crop in Indiana is very considerable, varying from half a million to a million dollars a year.

2. The occurrence of smut in oats may be completely prevented, at little trouble and expense, and by means entirely within the reach of every farmer.

3. Prevention is effected by treating the seed oats in such manner that all adhering spores of the smut are killed without destroying the seed.

4. The recently discovered hot water method of treatment is recommended as much superior to the copper sulphate method heretofore recommended.

5. The hot water method consists in immersing the seed grain for five minutes in water standing at first at 135° to 145° F., which may drop during the operation to 130°, or may fall even below 130° if the time is correspondingly prolonged.

6. After drying by spreading upon a floor the seed may be sown immediately or after a time, with equally beneficial results in either case.

7. This treatment not only removes the smut from the crop, but improves the growth and increases the yield.

8. The increased yield is sufficient to pay for the labor and trouble of treatment several times over.

[Pages 98 to 108 of this bulletin, containing tables of germinations and other data of interest to investigators chiefly, have been omitted from the larger part of the edition.]